2015-10

Energy Academic Group (EAG) at Naval Postgraduate School Energy Seminar

Nussbaum, Daniel

Monterey, California: Naval Postgraduate School.

Energy Academic Group (EAG) at Naval Postgraduate School

http://nps.edu/energy/

Energy Seminar

30 Oct. 2015

Agenda

- Bottom line up front (BLUF)
- EAG Background
- SECNAV Guidance
- EAG Pillars—Goals and Accomplishments
  - Curriculum
  - Outreach
  - Research
    - Recent Important Projects
    - Current Opportunities

BLUF

The Energy Academic Group (EAG, http://nps.edu/energy) has made measurable progress in

Curriculum Development and Delivery

- Masters -- 13 graduates, 21 currently enrolled
- Certificate -- 29 completed, 9 currently enrolled
- Seminars -- 100 Completed
- Executive Education -- 2 classes completed; 35 Flags/SES attended; Program formally embedded in Naval Flags curriculum; VERY strong support from ASN and OpNav senior leadership

- **Research**
  60 theses, 10 research projects
- **Outreach**
  US Government (defense and nondefense),commercial firms, academic institutions

and has specific plans for FY 16

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Energy Academic Group	Dep. Chair, EAG	Program Officer, EAG
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EAG Background

EAG charter May 2013

EAG mission *The overall objective for the EAG is to develop and maintain NPS as a Navy Center of Excellence for Energy Graduate Education and Research. The EAG will also actively explore educational and research partnerships across the full spectrum of Department of Defense (DOD) related organizations, Department of Energy (DOE), as well as other universities, industry, and non-profit sectors.*

SECNAV Energy Guidance

GOALS

CNO Guidance: Provide a Navy Energy Strategy that treats energy as a strategic resource

Ends	Ways		Means
Vision	**Strategic Imperatives**	**Targets**	**Enablers**
• A Navy that values energy as a strategic resource • A Navy that understands energy security as fundamental to executing the Navy mission afloat and ashore • A Navy resilient to any potential energy future	• Assure Mobility • Protect Critical Infrastructure • Lighten the Load • Expand Tactical Reach • Green Our Footprint	• Increase Efficiency Afloat • Increase Efficiency Ashore • Increase Alternatives Afloat • Sail the Great Green Fleet • Increase Alternative Energy Ashore • Reliable Power for Critical Infrastructure • Reduce Non-Tactical Petroleum Use • Energy Efficient Acquisition	• Leadership • Technology • Policy • Strategic Partnerships • Culture Change

Energy Security is having assured access to reliable and sustainable supplies of energy and the ability to protect and deliver sufficient energy to meet operational

VISION

Increase Alternative Energy Department-wide	By 2020, 50% of total Department energy consumption will come from alternative sources
Increase Alternative Energy Sources Ashore	By 2020, at least 50% of shore-based energy requirements will be met by alternative sources; 50% of Department installations will be net-zero
Reduce Non-tactical Petroleum Use	By 2015, Department will reduce petroleum use in vehicles by 50%
Sail the "Great Green Fleet"	Department will demonstrate a Green Strike Group in local operations by 2012 and sail it by 2016
Energy Efficient Acquisitions	Evaluation of energy factors will be mandatory when awarding contracts for systems and buildings

NPS is involved in EVERY aspect

EAG Pillars
Curriculum Development and Delivery

- 4 masters degree curricula-- OR, MAE, ECE, FM
  - Each curriculum does its own curriculum review with its own sponsor
  - N45 is overall curriculum sponsor and does overall curriculum review
- 1 certificate
- 1 Flag-level course ICW N00F, CEE and ASN (E,I, & E)
  - Contents under review and may change
- Energy Seminar for all-of-campus (energy and non-energy students, faculty, occasional CSU-MB, MIIS and Presidio persons)
- Student Intake
  - 10 students/year for masters
  - 9 for certificates
    - Recent successful curricula reviews at department levels
    - Recent N45 curriculum review, 23 July: Thumbs Up
    - RDML Morton, OPNAV N45, to visit January 2016

Other Curriculum Development and Delivery

- **Energy Security**
  - **NATO School**
  - **Indonesian Defense University**
  - **Technology for Information Operation**
- ~~**Systems Engineering – Energy track in SE DL Masters**~~
- **Critical Energy Infrastructure Protection**
- **Energy Efficiency in Expeditionary Operations (E3O)**

Curriculum Development and Delivery
Students enrolled and graduated

Master's Degrees		
Dept	**Students enrolled**	**Students graduated**
OA	5	0
ME	5	2
ECE	2	1
FM	9	10 (June 2015)

Certificate (Only)		
	9 enrolled	29 completed

Seminar / Speaker's Series

100 seminars with speakers from industry, government, and academia

Executive Education

FY13 -- 2 classes; 35 Flags/SES attended
FY14 -- Three classes delivered. Program formally embedded in Naval Flags curriculum . Very strong support from ASN and OpNav senior leadership
FY15-- Three classes delivered. N00F, CEE and ASN are rebalancing the Energy/Innovation mix.

Recent or Outstanding Curriculum Issues

1. **Increase EAG curricula student throughput**
   a) **Masters degrees**
2. **Create and Maintain fleet demand signal and career path for energy-trained officers.**
   a) **There is no energy career path/billet base**
      Current Zero-based subspecialty review????
   b) **Energy P-code is equivalent to "parent" code (i.e., FM, OR, MAE & ECE)**

Recent or Outstanding Curriculum Issues

3. Community Manager (Billets)
   a) Service the officer
   b) Career path
   c) Mentorship
   d) Fill Quotas
   e) Closed Loop Detailing

4. Some curriculum have overloaded matrices
   a) MAE
   b) FM

5. LIEAF contents adjustment

EAG Pillars
Research—Student and Faculty

	2010	2011	2012	2013	2014	2015
Student theses	49	14	43	43	84	35
Faculty Research	21	40	53	88	116	26

- Supporters and funding sources of for NPS Energy Research
  - DoN (Naval Research program, Acquisition Research Program, ONR)
  - USMC (Expeditionary Energy Office, Thesis Research Working Group)
  - IMET, OSD (AT&L)
- Examples of high payoff current energy research
  - Replenishment at Sea Planner (RASP; Prof Brown et al))
  - USMC Attitudes and Behaviors-- Energy Consumption and Conservation (Prof. A. Salem)
  - Gen Military Training--Energy (GMT, Prof. Sue Higgins)
  - Reduction Of Aviation Fuel Consumption Through Slot Management (Profs. Dixon, Szechtman, Apte)
  - Energy Management Systems to Reduce Electrical Energy Consumption- Hardware (Profs Julian and Oriti)
  - CVN Speed of Advance and Removal of PIM Restraints (Prof. Nussbaum; Mr. Howard)
  - Energy Systems Technology Evaluation Program (ESTEP) (Profs Regnier, Nussbaum)
  - PACOM Refinery Capacity Analysis: Final Report (Prof. Alderson)

RSPO and EAG are Developing Data Base of NPS Energy Research Efforts

EAG Pillars Outreach

- Answer and support SECNAV mandates
- Create community of interest among those interested in energy
- Exhibit capability of NPS as a center of excellence
- Build tools and share resources

Outreach Overview

EAG has built relationships to provide…

- Enhancement of NPS's core mission
  - ***Graduate Education*** of Naval officers
  - ***Faculty Research*** to support that mission
  - ***Non-degree Education*** programs to support that mission
- Awareness of NPS's capabilities
- Opportunities to work collaboratively

- **OPNAV/SECNAV/HQUSMC**
- **Departments of Army and Air Force**
- **OSD—AT&L; DLA**
- **Department of Energy– Sandia; Livermore; Idaho national Labs**
- **NPS Energy Seminars (other universities; commercial entities,…)**
- **Other**
  - **Indonesian Defense University**
  - **NATO Energy Security Center of Excellence**
- **PACOM J4**

Outreach: Defense Seminar Series

Outreach: Defense Seminar Series

Academic Institutions	Research Laboratories/Institutions
• NPS, Stanford • CalTech • UC-Berkeley • UCLA • Idaho State • Massachusetts Institute of Technology • Colorado School of Mines • Colorado State • *Georgia Tech* • *University of Texas, Austin*	• Idaho National Labs • Lawrence Livermore • Sandia Labs • Pacific Northwest National Labs • Monterey Bay Aquarium Research Institute • Electric Power Institute • California Institute for Energy and Environment, University of California • Navy Renewable Energy Lab • Center for Naval Analyses

Outreach: Defense Seminar Series (con't)

Industry / Private Sector	Government
• Rocky Mountain Institute • IBM Senior Research Division • Babcock & Wilcox • Tesla Motors • Yardney Technical Products • Pathfinder Partners • Aera Energy LLC • American Public Power Association • Pacific International Center for High Technology Research	• Director for Operational Energy, DOE • Director, Navy Energy Coordination Office (OPNAV N45E) • State Department • Secretary of Defense • Defense Logistics Agency • HQ USMC • Naval Surface Warfare Center, Crane • NDW Command Information Officer (N6) • Center for Naval Analyses • NASA Ames Research Center

Examples of NPS Current and Recent Energy Research

A BCA For Transitioning The U.S. Navy From Petroleum To Synthetic Fuel Resources

Objectives:

The purpose of this study is to show the conditions where domestic coal to liquid (CTL) fuel production facility investment is financially practical, as well as those where it is financially impractical.
This analysis develops cost estimates, provides business case analysis and reviews global estimates for developing a coal to liquid synthetic fuel production facility.
It identifies and qualifies risks and sensitivities.
It also examines various projected coal and crude oil markets and how each case influences the decision to pursue a synthetic fuel program.
It concludes with a decision matrix comparing the pursuit of a synthetic fuel program with maintaining the status quo of the use of fuel from petroleum.

Description: *" Methodology"*

• Collect cost data on various synthetic fuel plants from public and private sources
• Organize data into two major components, CAPEX and OPEX
• The CAPEX and annual OPEX data were merged to find total program cost, or life cycle cost (LCC) over a given period, initially calculated over a period of 30 years.
• Discounted cash flow (DCF) and internal rate of return (IRR) analysis were used to estimate a minimum retail selling price of the synfuel product for the life of a plant.
• Retail selling price was examined over various possible coal and crude oil prices over the life of the plant to develop a decision space for pursuing a synthetic fuels program

Key Deliverables:

- The minimum retail selling price is an increasing function of the internal rates of return. That is, the higher internal rates of return that is required, the higher the minimum retail selling price.
- The minimum retail selling price is a decreased function of the plant life.
- While the minimum retail selling price is a decreased function of the plant life, it is decreasing at a decreased rate.
- Jet fuel from petroleum price was highly variable over the evaluation period.
- Synthetic jet fuel pricing remained relatively stable over the evaluation period.
- Jet fuel pricing was very sensitive to price fluctuations, while synthetic fuel was far more stable.
- Synthetic fuels price insensitivity relative to coal price fluctuation is due ot the large CAPEX costs relative to the cost of the feedstock.
- For the landscape of possible projected prices for crude oil and coal, 57% of the cases favored synthetic fuel and 43% of the cases favored fuel from petroleum.

Key Participants:

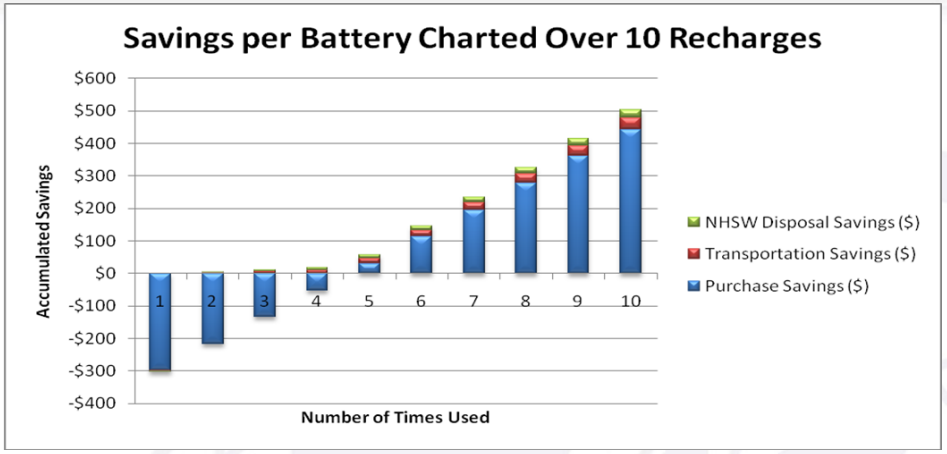
LCDR Michael Benedetto, USN
Thesis Advisor: Dr. Daniel Nussbaum
Second Reader: Ira A. Lewis

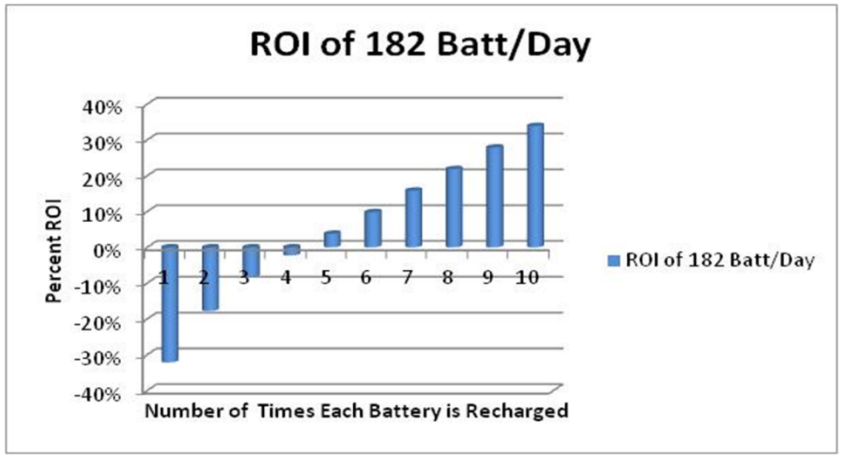
NAVAL POSTGRADUATE SCHOOL

The Impact of Rechargeable Batteries

Research Questions

1. What are the cost differences in purchasing, investment, and operations and maintenance (O&M), between current disposable BA-5590 batteries and the BB-2590 rechargeable batteries?
2. What are other quantified benefits, such as transportation and disposal savings, of using rechargeable batteries?
3. Will rechargeable batteries lighten the load of a Marine Corps infantry battalion?





In first 30 days, all investment costs recouped, $174,418 saved, and 34% ROI.

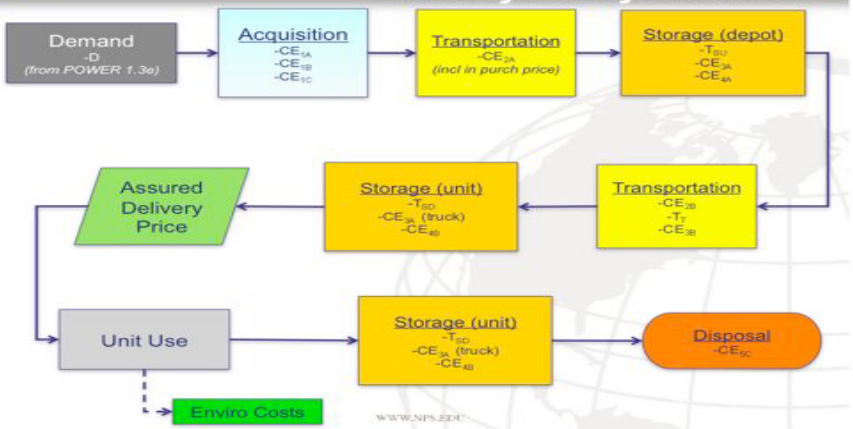
Rechargeable Batteries: The Bottom Line

- Rechargeable batteries save money as a function of demand and number of times recharged with a rapid payback
  - $15,017 saved per day per battalion ($82.51 * 182)
  - $450,505 saved per month per battalion ($15,016.82 * 30)
- Rechargeable batteries weigh less when used more than six days
- Rechargeable batteries reduce convoys from external units because battalions are more self-sufficient, thus rechargeable batteries
  - Save lives
  - Save resources (manpower, trucks, fuel, ect)
  - Reduce a potentially critical material shortfall
- The more batteries you need, the more you save by using rechargeable batteries- positive return on investment
- Rechargeable batteries should be the warfighter's first choice for batteries

NAVAL POSTGRADUATE SCHOOL

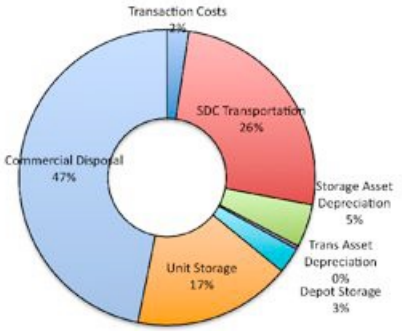
BATTERIES ON THE BATTLEFIELD: DEVELOPING A METHODOLOGY TO ESTIMATE THE FULLY BURDENED COST OF BATTERIES IN THE DEPARTMENT OF DEFENSE

Scenario 1 (CC… Battery Lifecycle Model



Scenario 1: Base Case FBCB

Scenario 1
Cost Elements as Percent of Total Budens
(nonzero burdens only)



- We developed a methodology for determining the FBCB.
- Tested methodology through CONUS and OCONUS/tactical scenarios
  - CONUS: 9.3% increase over contract price
  - OCONUS: 12.85% increase over contract price
- Usage scenarios greatly affect the assured delivery price. The use of aviation assets as part of a scenario increased the cost of batteries significantly
- Disposal: Reduction of the waste stream associated with $LiSO_2$ batteries would most readily result in cost improvements.
- Discrepancy between contract price and AMDF/FEDLOG price. Why?
- This methodology can be used by the acquisitions community for determining LCC of any system dependent on delivered energy.
- Methodology can be implemented in a spreadsheet and lends itself easily for use in AoA.

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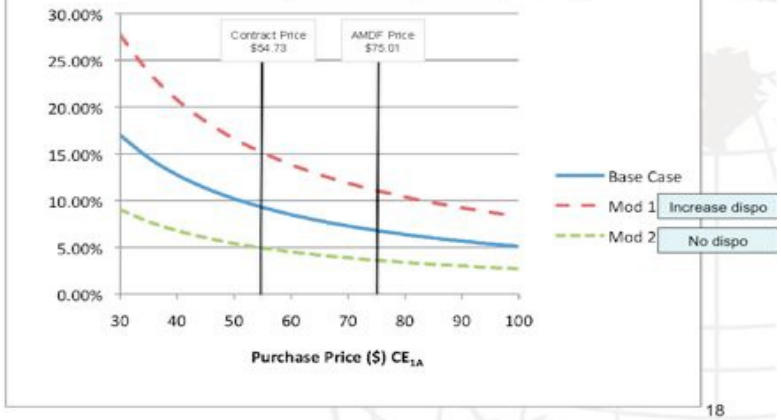
Scenario 1 Total burden as a percentage of the purchase price (FY00$)



18

NAVAL POSTGRADUATE SCHOOL

Active Load and Source Management for Tactical Power Systems

Background:

Existing tactical power systems are largely unmanaged, resulting in:

- **Production capabilities that are overspecified and underutilized.**
- **Load management that is *reactive* rather than *predictive* and *deliberate.***

Current attempts at intelligent management :

- **Small-scale (single shelter, vehicle, or command center).**
- **No energy scheduling. Limited to matching immediate demand to immediate availability.**

Scope of Research:

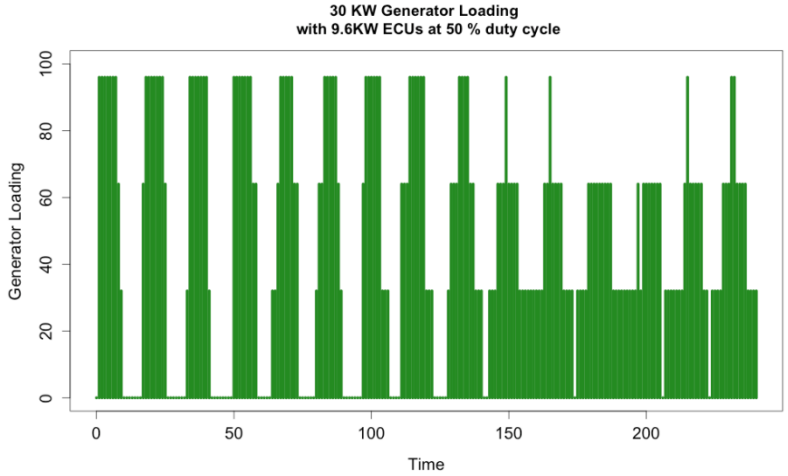
Evaluate impact to deployed equipment requirements, fuel savings, and energy availability risk through:

Intelligent load management
- **Time-share generator capacity**
- **Non-critical load shedding and recovery**

- **Scheduled performance of time-insensitive tasks**
  - **Heating/Cooling**
  - **Energy storage replenishment**
  - **Water production**
- **Incorporation of energy storage and locally generated renewables.**

Simulated generator operation with unmanaged loads.

- Consumption as percentage of capacity shown in green. ***Unpredictable*** and ***unmanaged*** peaks prevent connection of additional loads.
- White space indicates ***wasted capacity*** and ***inefficient operation***.



Objectives:

Quantify potential improvements of an actively managed tactical power grid:

- **Amount of equipment procured, fielded, maintained, and retrograded.**
- **Forward fuel consumption.**
  - **More efficient generator operation**
  - **Actively managed renewables and storage**
- **Operational energy availability and risk.**

NAVAL POSTGRADUATE SCHOOL

Optimization of Fuel Staging in the Pacific

Background:

NPS has been involved in developing many network models for fuel distribution at specific locations in the Pacific.

N81 has commissioned a study of the vulnerability of fuel moving across the Pacific by tanker in support of campaign-level logistics needs.

Thesis student: **LT Jason Marks**
Advisor: **Professor David Alderson**
Second Reader: **CDR Peter Ward**

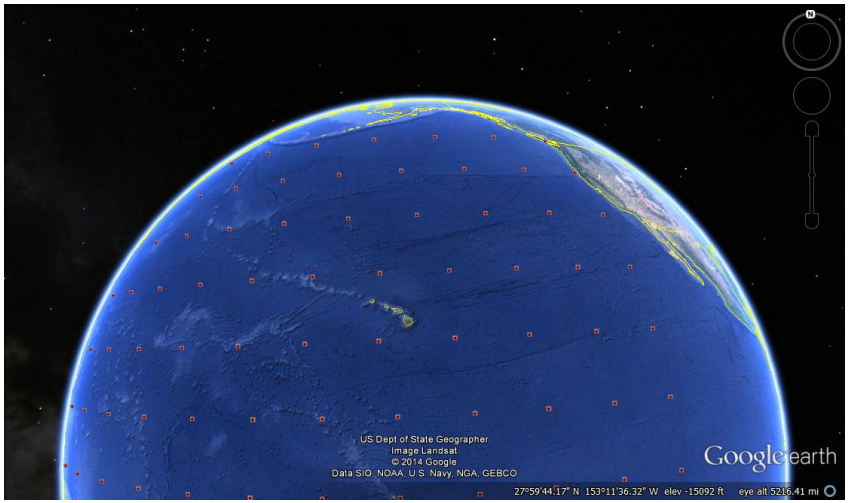
Scope of Research:

This study will look at fuel transported from the western United States to the western Pacific using a network model.

We can then extend the model to include attacks being launched against tankers transiting the network.

Finally, we can apply the ability to provide escorts for tankers transiting certain routes and calculate the best way to distribute a given number of available escorts.

One Potential Network



Objectives:

Assess the risk to a campaign imposed by threats against the logistics network providing the fuel for it.

Apply escorts sequentially to determine if a certain number can roll back most of the risk, or if there is a clear point of diminishing returns.

Inform decisions regarding allocation of combatant units between the campaign itself, and defense of the strategic lines of communication.

NAVY ENERGY

Thesis

Alternative Practices To Improve Surface Fleet Fuel Efficiency

- Change of policy or business practice to reduce fuel consumption
- No overhead costs as with engineering changes
- Can be changed with the stroke of a pen

Potential Policies To Change

- Drift Operations
- Single Generator Operations
- Minimum Fuel Safety Levels in 5th and 7th Fleets
- Transits
  - TFP (Transit Fuel Planner)
  - Remove PIM (Plan of Intended Movement) moving window

Background

- Budget cuts are forcing a reduction in spending
- The Navy's Surface Fleet spent over $1.7 billion in fuel in FY 2013
- Engineering changes take years to reap the benefits
- The only way to get immediate savings is through policy change

Policy	Platform	Change to Policy	Impact
Drift Operations	DDGs/CGs	Encourage six hours per night of drift operations during 10% of underway nights	$14.1 million/year saved
Single-Generator Operations	DDGs/CGs	Encourage single-generator operations 25% of the time underway	$27.4 million/year saved
Minimum Fuel Safety Level	MSC Ships	Using RASP, reduce the minimum fuel safety level from 60% to 50% in both 5th Fleet and 7th Fleet	$18.5 million/year saved
Transits	DDGs/CGs	Utilize TFP for all transits	Up to 21% reduction in transit fuel consumed
Transits	DDGs/CGs	Relax or remove the moving window within PIM	May be greater than 19% reduction in transit fuel consumed

NAVAL POSTGRADUATE SCHOOL

Optimal Scheduling in Tactical Power Systems

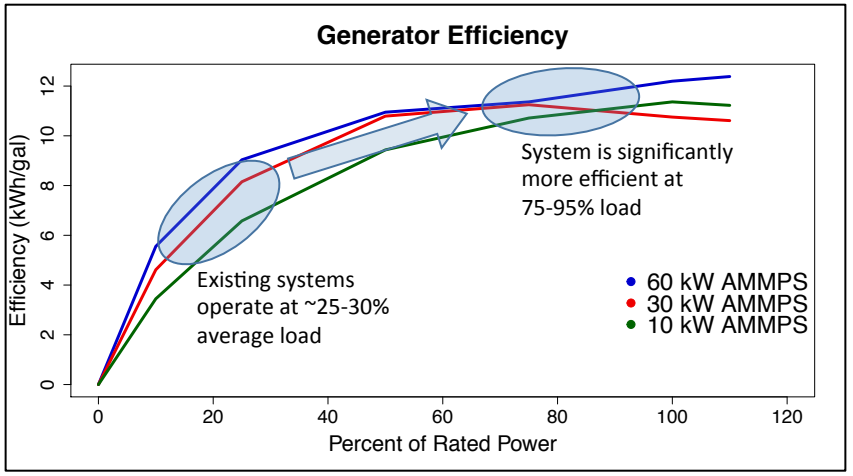
Background:

Existing tactical power systems are:

- **Load following – they require sufficiently available production to meet unmanaged spikes in demand.**
- **Inefficient - low average generator utilization (25 - 35%) leads to excessive fuel consumption.**
- **Reactive – conditions at any time are the result of several independent, naïve, and locally greedy decisions.**

Current solutions are:

- **Small-scale (single shelter, vehicle, or function).**
- **Production focused, controlling energy production and storage but not consumption.**



Unmanaged peak demand requires that we tolerate significant periods of ***low utilization*** and ***poor fuel efficiency***.

Objective:

Quantify potential fuel efficiency gains from optimal scheduling of tactical generators and electrical loads.

Methodology:

Employ mixed-integer linear programming to create near-optimal generator and environmental control unit (ECU) schedules that minimize fuel consumption.

Determine sensitivity by analyzing across variations in:

- **Generator and load configurations**
- **Energy storage characteristics**
- **Proportion of unmanaged electrical load**
- **Demand uncertainty**

Findings:

- **Up to 28%fuel savings in the baseline configuration.**
- **Strong where legacy systems are weakest: shows greatest efficiency gains at low duty cycles and low generator loading.**
- **Complements energy storage. System can choose to perform work now, or store energy–at a loss–to do work later.**
- **Extends capabilities. Schedules generator output to permit connection of additional equipment without overload.**
- **Requires components of "smart grid" technology to monitor system and control loads.**
- **Based on principles currently used in commercial and residential utilities and electric vehicle fleet management.**

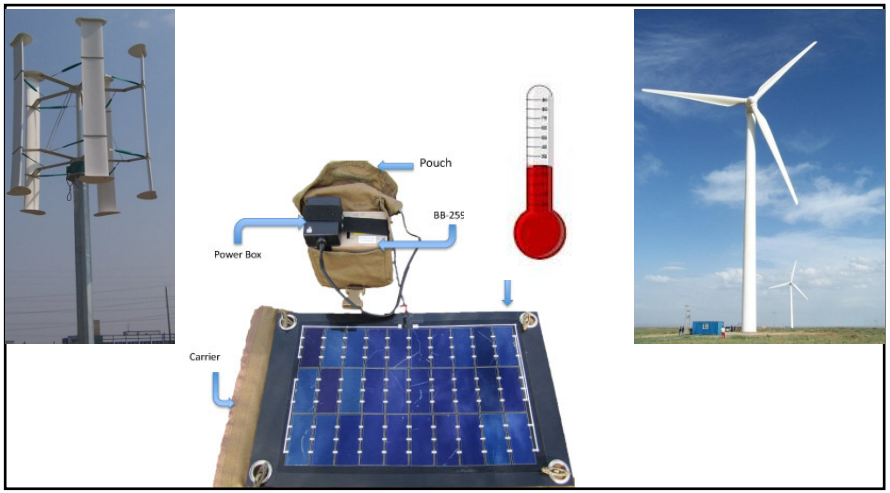
LCDR John Sprague jgspragu@nps.edu Aug 2015

Cost-Benefit Analysis of Energy Demonstration Projects
CBA-ED

Drs. Eva Regnier, and Dan Nussbaum Naval Postgraduate School, Monterey, CA 93943;

Description / Objective:

- The goal of this project is to develop tools to evaluate the benefits and costs of technology demonstration projects for the ESTEP program
- Provide economic and cost analysis support to agencies participating in ESTEP, including
  - Benefits and costs include those directly attributable to the demonstration and
  - Benefits of information derived from demonstration projects and
  - Potential benefits of the technology if successful and widely deployed



Approach:

- **Analytic techniques including**

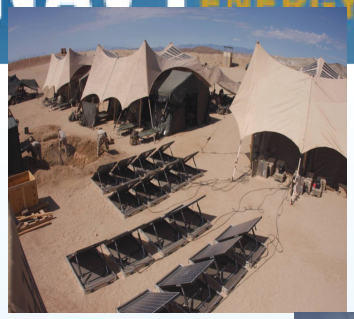
  Cost-benefit analysis, return-on-investment investment valuation and option value analysis
- **Education and Learning Opportunities**
  - MS Theses
  - Integration with NPS Energy MS degree and executive education curricula
- **Collaboration with demonstration project teams**

Expected Products / Payoff:

- **A toolbox of cost and economic analyses that permit evaluation of the ROI of energy demonstration projects.**
- **Methods for assessing value of non-monetary benefits of energy technologies for Navy mission-critical energy services**
- **Investment valuation tools adapted to Investment valuation tools for mid-range TRL technologies**
- **Return-on-investment support for ESTEP technology demonstration projects**
- **Development of Navy energy professionals with analytic capabilities and experience**
- **Other, specific products: Benefits checklist, Learning value checklist, Storage value spreadsheet, and Technology Integration Readiness Levels**

Energy Efficient Outpost Modeling Consortium (EEOMC)

Office of Naval Research (ONR)
Department of Energy Building Technologies Office(DOE BTO)
Naval Facilities Engineering Command Navy Expeditionary Program Office (NAVFAC NEPO)
Army Communications-Electronics Research Development & Engineering Center (CERDEC)



Revolutionary Research . . . Relevant Results

MOTIVATION:

- The move toward increased use of renewables in the battlefield is accompanied by a new set of challenges.
- Determining the optimal balance of energy resources, their integration into a microgrid and their optimal operation is crucial to appreciably improving battlefield fuel consumption.
- In order to do this the DOD requires new system-level energy modeling tools to aid in decision-making by mission planners and operational commanders.

PROGRAM PLAN/DESCRIPTION:

An integrated DOD-DOE team will execute this program featuring a university-led consortium to engage small businesses and non-traditional players. This group will develop:

- Energy Resource Planning Tool to better optimize power resources at contingency bases
- Energy Resource Dashboard to improve energy efficiency during base operation
- Energy Efficient Training program to train leaders and accelerate the adoption of these tools.

MILITARY BENEFIT:

EEOMC will provide:

- The tools to optimize the mix of energy technologies to significantly improve energy efficiency of contingency bases;
- Provide mission commanders the knowledge about resource performance to allow for maximum impact of these technologies and the ability to control the use of these resources leading toward decreased battlefield fuel consumption.

EEOMC Plan

- Four year program initiated in June 2013 to develop and demonstrate:
  - Energy Resource Planning Tool to better optimize power resources at contingency bases.
  - Energy Resource Dashboard and Control to improve energy efficiency during base operation.
  - Energy Efficiency Education program to train leaders and accelerate the adoption of these tools.

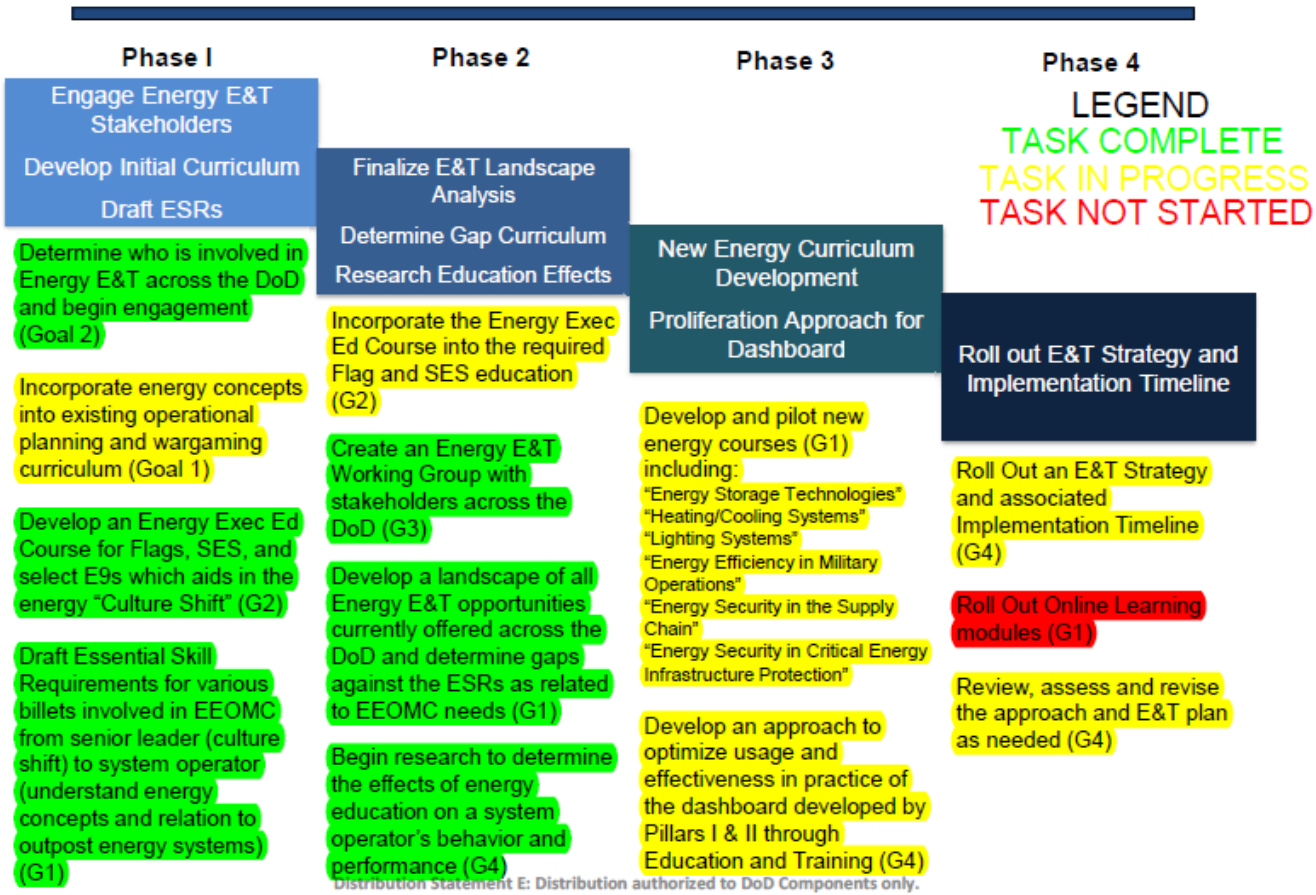
- The integration of the above three pillars will result in a balanced combination of tool development and training which will:
  - Significantly improve the energy efficiency of contingency bases in the near future
  - Continue to highlight the importance of battlefield fuel consumption and conservation.

EEOMC Pillars

- Energy Resource Planning Tool
  - Modeling tool to determine optimal mix of power resources (generators, renewables, and energy storage) for a given operational scenario and loads
  - Evaluate impact of emerging energy efficient technologies
  - Simplify choices and provide recommendations to mission planners
- Energy Resource Dashboard & Controls
  - Dashboard 'app' to provide outpost commanders real-time monitoring of energy resources
  - Integrated suite of sensors and controls to monitor and manage sources and loads to improve energy efficiency during base operations
- Energy Efficiency Education
  - Coursework which incorporates evaluation of energy concepts into operational training and planning
  - Accelerate the adoption of these modeling tools

Pillar 3 Goals Progress

Pillar 3 Phases



Course Structure

- Executive Seminar: "**Operational Energy in Military Operations**"
  - Flag Officers, General Officers, Senior Executive Service
  - Joint Service
  - One-day, facilitated discussion
- Career Course: "**Energy Strategy in Expeditionary Operations**"
  - Junior to Mid-level Officers and Staff NCOs
  - Joint Service, any military specialty
  - Two-day, lectures and discussion
- Operator Course: "**Energy Efficient Outpost Operations**"
  - Junior Officer, Staff NCOs, and NCOs
  - Joint Service, expeditionary base operations personnel
  - Three-day lectures, discussion and practical application

Examples of NPS Research Opportunities

EAG Pillars
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  - IMET, OSD (AT&L)

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Current Research Opportunities (includes travel funds)

- Designing and Operating Self-Organizing Micro-grids for Civilian and Military Applications
- Remote Sensing for Smart Renewable Power
- CyCIT-WS: Cyber Critical Infrastructure Threat Warning Stream
- Energy Leadership Informatics Institute
- Resilience Processes in Positive Case Studies
- Underwater Optical Communications on a Real-Time Sensor Mooring Deployed in Tempe Town Lake

- Heterogeneous surface wettability for manipulation of dryout hydrodynamics and bubble departure during high-heat-flux boiling processes
- Low cost catalyst for portable hydrogen generation and on-demand power
- Fundamental studies on composition/ performance correlations for aviation fuels
- Towards vetted sensing and control system firmware and software
- GaN interface engineering for naval RF power electronics applications via atomic layer epitaxy
- Unlocking the chemistry of the amine-thiol universal solvent system for solutionprocessed, flexible electronic devices

Current Research Opportunities (includes travel funds)

- Combat Power Monitor: Non-invasive Load Monitoring (NILM) of shipboard power systems.
- Higher energy density Lithium-ion batteries.: Exploiting Oxygen Anion Redox for High-energy Rechargeable Lithium Batteries
- Thermal Management Technologies for Low-Temperature Undersea Dive Persistence: a Novel Arctic Diving Suit: Passive (materials with improved insulating properties) and active (energy harvesting from environment) approaches to allow longer operating times during cold-water dives.
- Determination of the Impact of Chemical Composition on Measured and Predicted Fuel Properties and on Combustion in Military Diesel Engines

BLUF

The Energy Academic Group (EAG, http://nps.edu/energy) has made measurable progress in

Curriculum Development and Delivery

- Masters -- 13 graduates, 21 currently enrolled
- Certificate -- 29 completed, 9 currently enrolled
- Seminars -- 100 Completed
- Executive Education -- 2 classes completed; 35 Flags/SES attended; Program formally embedded in Naval Flags curriculum; VERY strong support from ASN and OpNav senior leadership

- **Research**
  60 theses, 10 research projects
- **Outreach**
  US Government (defense and nondefense),commercial firms, academic institutions

and has specific plans for FY 16

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